THE WESTERN GAS CONSTRUCTION CO.

GAS ENGINEERS AND BUILDERS

SAN FRANCISCO FORT WAYNE, IND. NEW YORK

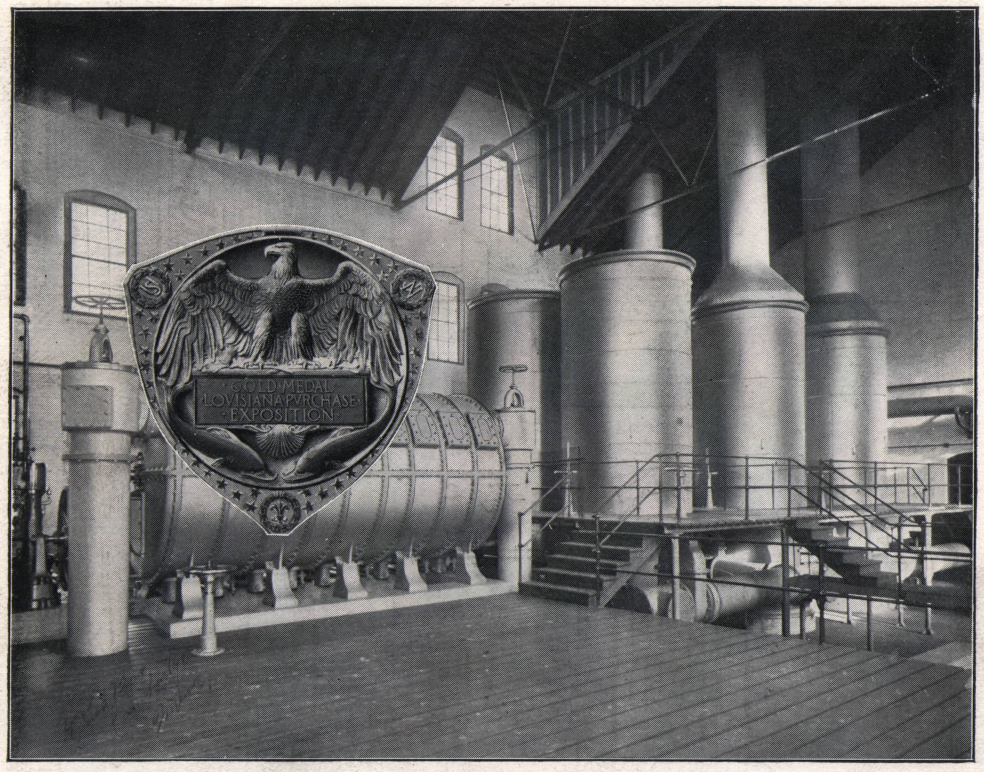
Bulletin No. 201 B.

THE "WESTERN GAS" SYSTEM

—OF—

COAL GAS CONDENSERS,

WERE AWARDED



GOLD MEDAL

AT THE LOUISIANA PURCHASE EXPOSITION, ST. LOUIS, 1904,

—FOR—

Correctness of Principle and General Excellence of Design.

No. 790,297. PATENTED MAY 23, 1905.

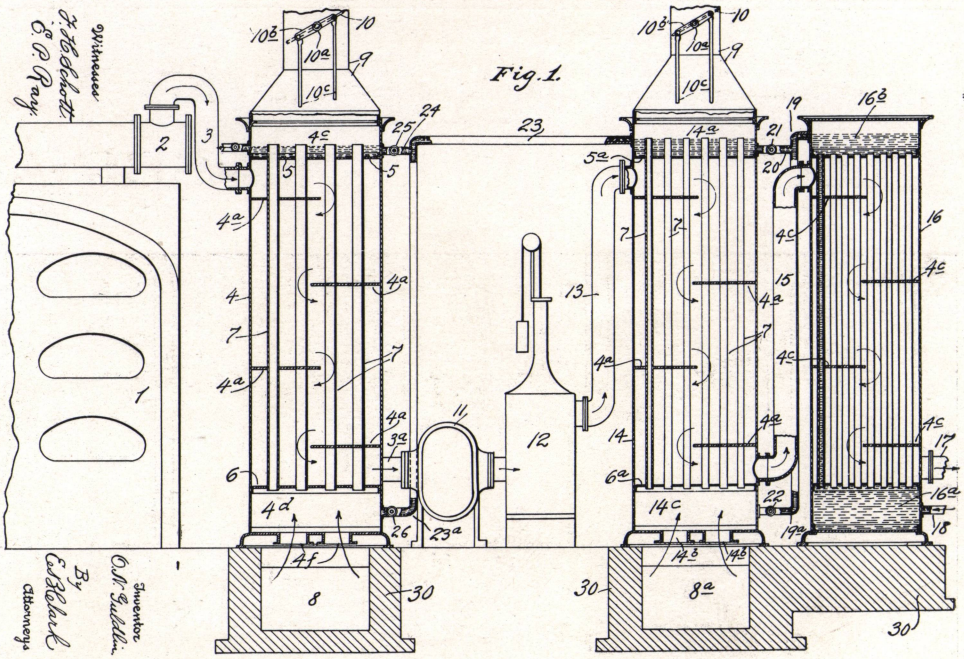
O. N. GULDLIN.

GAS CONDENSING APPARATUS,

Application Filed Dec. 1, 1902.

Witnesses:
F. B. Schott
C. P. Ray.

Fig. 1.



Inventor
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Witnesses:
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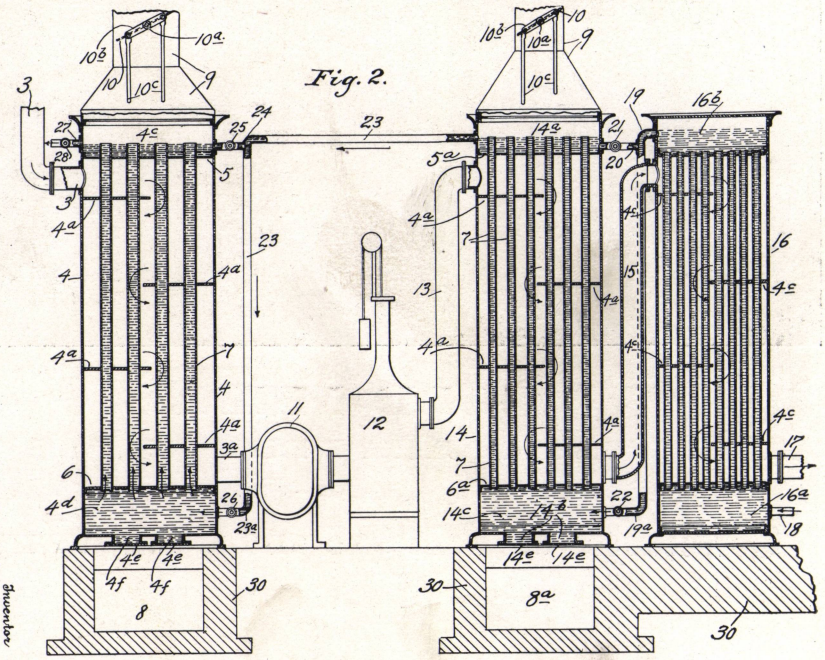
C. P. Ray.

Fig. 2.



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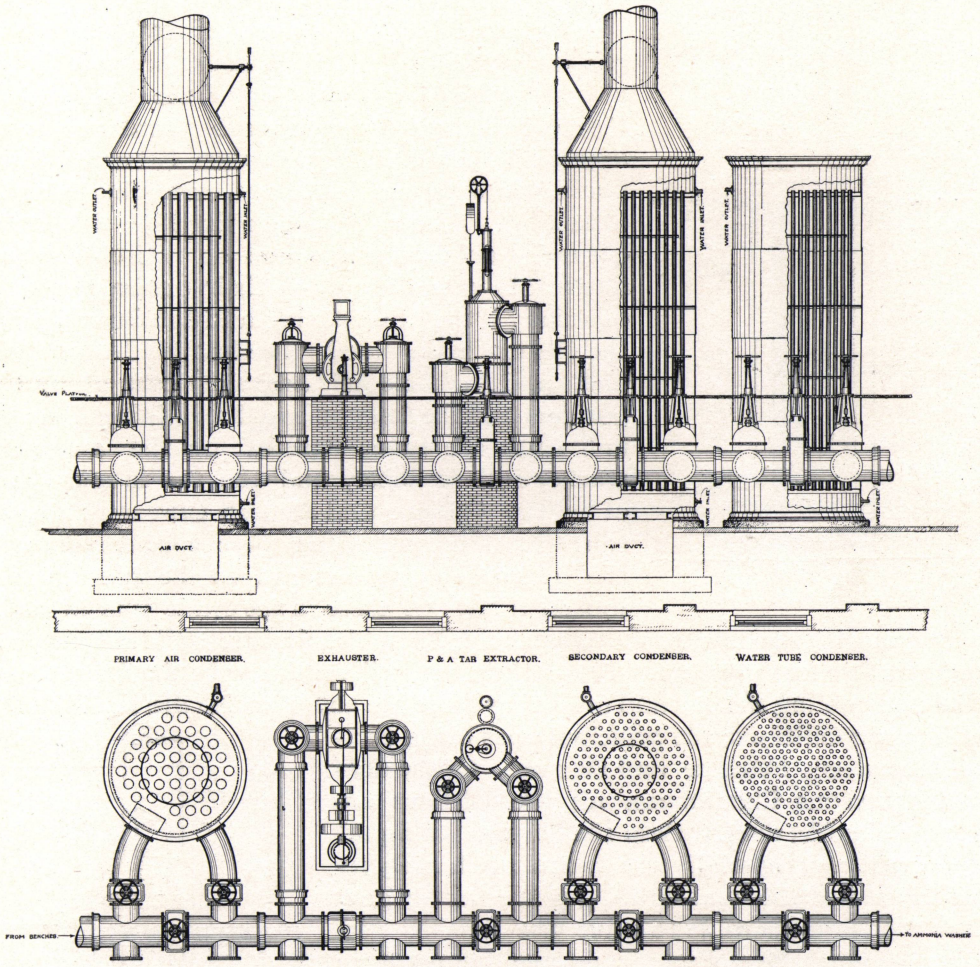


Fig. 3.

GAS CONDENSERS.

Meaning of Condensation.

While the general system of coal gas condensation has been explained in our bulletin No. 201, this bulletin will deal only with that portion of the apparatus which effects condensation by change of velocity and reduction of temperature of the gas. It is generally admitted that the gas must be condensed, but while the terms should be understood as meanimg liquefaction and removal of undesirable vapors, both by liquefaction and by chemical and physical absorption, it is often taken as meaning simply the removal of heat, or in other words cooling the gas. The removal of the heat from the gas is not in itself the principal point, but it is incidental as producing conditions for the removal of undesirable components of crude gas.

What is to be Dealt With.

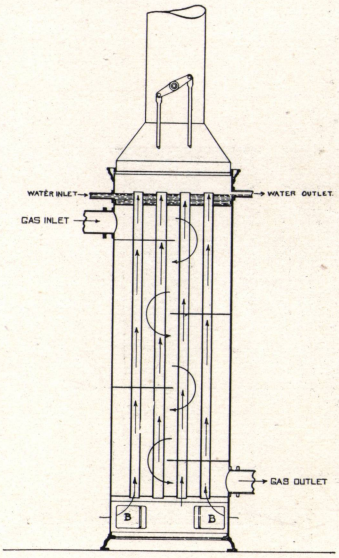


Fig. 4.

Care of Hydro-carbons.

To determine the method of treating crude gas its general composition must be considered, also the desired composition of the finished gas. Besides the desired components, there may also appear in the finished gas some Nitrogen, Carbonic Acid, Aqueous Vapor and even minute traces of Sulphur. The advantage gained by either the consumer or producer would be entirely incommensurate with the cost of their *entire* removal, especially if the illuminating and heating values of the gas are maintained. The last Hydrogen Sulphide and Carbonic Acid are taken care of by the purifiers and the Ammonia and remaining Ammonium salts are taken care of by the ammonia washer and scrubber, and the tar is taken care of by the Pelouze and Audoin tar extractor, so that in the apparatus here considered, it is the hydrocarbons that are to be particularly looked after. Of these in the crude gas in sufficient quantities to notice, the most complex molecules are solid at normal temperature and pressure. These therefore, will naturally be the first to condense on cooling the gas and following these are those which are liquid under ordinary conditions; the principal ones being Benzol, Amylene, Pentane and Hexane. Of the normally gaseous illuminants, all the Olefines are very valuable, nevertheless the vapors of liquid hydrocarbons, especially the Benzol are largely relied upon for the real lighting power of the gas. It is therefore desirable to have the finished gas carry as much Benzol vapor as the temperature and pressure conditions of distribution will allow.

Benzol Vapor.

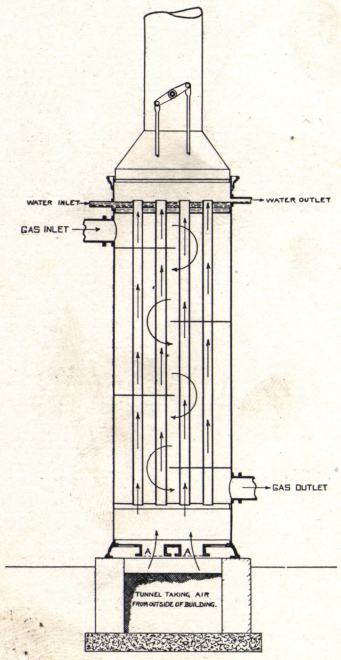


Fig. 5.

Vapor Tensions.

This brings us to the most important point in condensation and that is the matter of vapor tensions. As we have a mixture of vapors to deal with, it is well to know that the partial tension of each component of the mixture is always less than its respective vapor tension when alone at the same temperature and pressure. With this qualification, Dalton's law of vapor tensions holds practically good for our range of temperature; that is; in the space already occupied by the gas, a liquid ultimately evaporates to the same extent as in vacuo, the process being merely more slow.

Dalton's Law.

To retain in full relative tension the desirable vapors, it is necessary to remove the heavy tarry matter at as high a temperature as may be after leaving the hydraulic main, because the power of the tar and heavy oil vapors to absorb the lighter hydrocarbons increases with the decrease in temperature. In actual commercial operation of a coal gas works, however, there will always be more or less Naphthalene formed in the retort, and as the tar is a very good absorbant for this troublesome substance, the absorbant power of the tar increasing with the reduction of temperature, it is desirable on this account to leave the tar in contact with the gas to such temperature that the excess of naphthalene will have been absorbed by the tar and at the same time to avoid having the temperature go so low as to permit the tar to absorb too much of the benzol and other light giving hydrocarbons.

Tarry Matter.

Absorbs Naphthlaene.

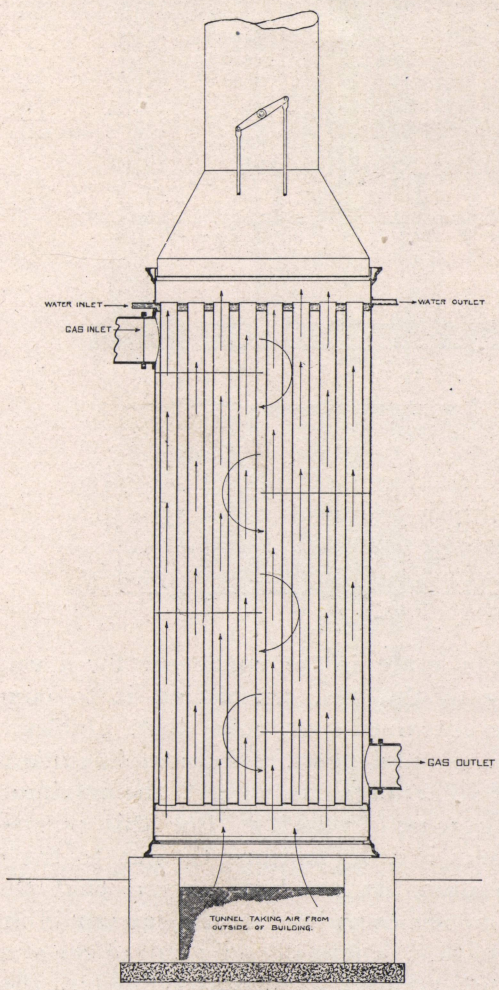


Fig. 6.

Long experience and very careful experiments have demonstrated that in common practice 90° F., may be taken as the lowest temperature to which the gas should be permitted to go before removing the tar, and in many cases the temperature at which the tar should be removed may be considerable higher than this, due to local conditions as to methods of distillation, character of coal, etc. It is therefore necessary that the first stage of cooling of the gas shall be under absolute control so as to reduce the temperature of the gas properly without passing this limiting temperature. In order to prepare the gas for the removal of the tar, as explained in our Bulletin No. 201, our Primary Condenser has been designed and with the most gratifying results. The temperature at which the gas may arrive at the Primary Condenser from the hydraulic main will vary of course with local conditions as to character of apparatus and method of distillation, distance of condenser from the retort house, etc. In most gas works the temperature of the gas on arriving at the Primary Condenser will range at about 140° F., in some instances as high as 165°

Temperature Limit.

Must be Controlled.

Primary Condenser Does it.

Elastic Capacity.

and in a few special cases, as for instance, where dry collecting mains or anti-dip arrangements are installed, or as in the case of by-product coke ovens where the condensers have sometimes to be designed to handle gas arriving at a temperature of 300°F., or more. It is, therefore, of course necessary that the primary condensers shall have great elasticity in their application to this work, that is to say must be very easy of regulation for handling the entering gas of wide range of temperature.

High Temperature.

Regulation.

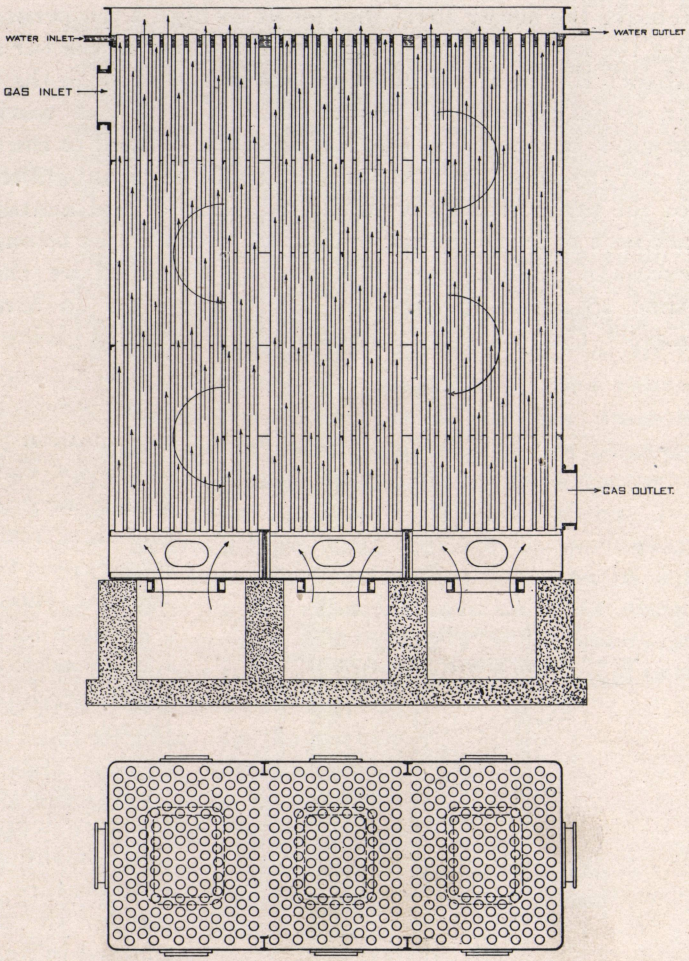
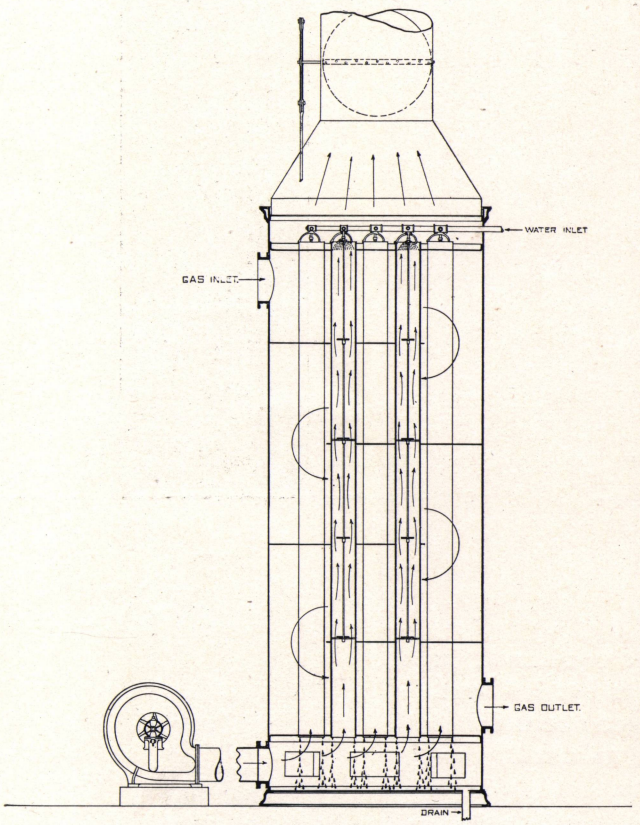


Fig. 7.

Our primary condensers are made in several types, according to the work to be done by them; being proportioned so as to accomplish two principal points; first, to get sufficient gas space in the condenser for a very considerable reduction in the *velocity* of the gas, permitting it to come almost to a state of rest to allow the entrained soot, coke dust, globles of pitch, tar and heavy oils to agglomerate and deposit. To accomplish this to the best advantage the condensers are so arranged as to get the maximum of frictional effect possible with such decrease of velocity. For this purpose baffle plates are introduced in condensers, in order to cause the gas to travel crosswise instead of lengthwise of the tubes It has been argued that this method would result in a decrease of efficiency, because the gas would impinge on but one side of each tube, so that practically only halt of the area of tube surface should be figured, but our careful experiments have proven that this argument was entirely groundless and based on an erroneous hypothesis.

Designed According to Requirements.

Velocity and Frictional Effect.



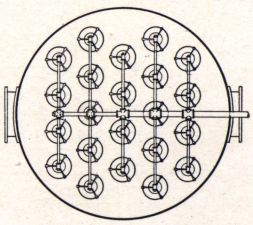


Fig. 8.

As a matter of fact this method of circulation causes eddies in the gas which make it fully envelope each tube in such a manner that no portion of the gas passes through without coming in contact with some of the tube surface.

Sinuous Paths of Gas.

On page 2, will be found reduced fac-similes of patent office drawings, Figs. 1 and 2, which show the arrangement of the condensers typifying our coal gas system which is protected by United States patent No. 731,412; drawing and claims of which are given in Bulletin 201, and also protected as Gas Condensing Apparatus by the United States patent No. 790,297; application for which filed December 1st, 1902. The claims of this patent which were allowed October 28th, 1904, will be found on page 19 of this bulletin

System Patented.

Figure No. 3 shows part sectional elevation and plan of the sequence of condensing apparatus, showing relative positions of the several units of the condensing system.

Normally, the primary condensers are all made to cool the gas by the action of air currents upward through the flues. Two styles of inlets for the air are used either admitting the air through large doors on the side of the bottom chamber of condenser as shown in Figure 4, or through openings in bottom head of condenser receiving the air from tunnel leading from the outside of the building, as shown in Figure 5. In either case the air inlet nozzles to bottom chamber of condenser are provided with doors or covers which may be secured in place should it become desirable to use water for the cooling agent as described later on.

Types of Primaries.

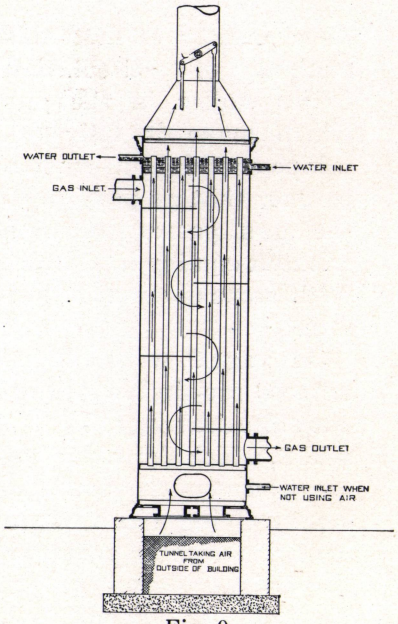
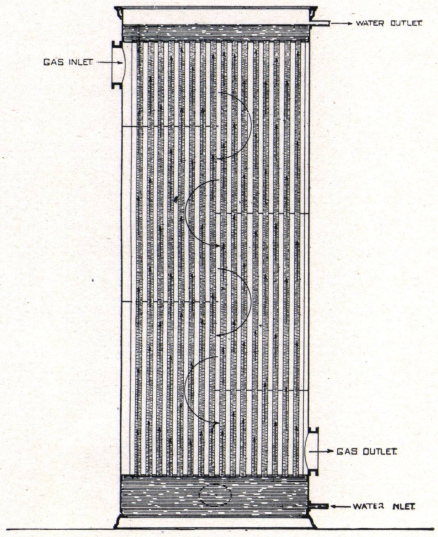


Fig 9.



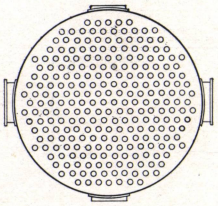


Fig 10

Large Units.

Figure 6 shows a larger condenser, in which the same principle is carried out. Figure 7 shows a still larger one which is of rectangular form, such as usually installed for very large plants.

High Temperature

When the gas is received by the primary condenser at an extremely high temperature, as for instance at 300° F., it is then necessary to remove an enormous amount of heat from the gas to bring it down to a proper temperature and the reduction from such very high temperature, to say 120° F., may safely be done very rapidly, as a sudden cooling *through that range* will not reduce from the gas any of the desirable vapors beyond what will be done in later treatment, and therefore advantage can be taken of special means for reducing the temperature and the method of doing this does not interfere with using the same condenser when desired, in the same manner as an ordinary air condenser, as shown in Figure 8, in which the general construction of the condenser is the same as in Figure 4, but with the addition of means for spraying water onto the inside surfaces of the flues and getting by mechanical means a strong circulation of air upward through the tubes, thus carrying away the evaporated moisture and keeping the aqueous vapor tension always at a minimum in the air in the flues, thus greatly facilitating the evaporation of the water with its consequent greater absorption of heat and resultant cooling effect on the tubes, and the gas surrounding them. The water sprayed into the tubes, will be slightly in excess

Special Apparatus.

Vaporizing Condenser

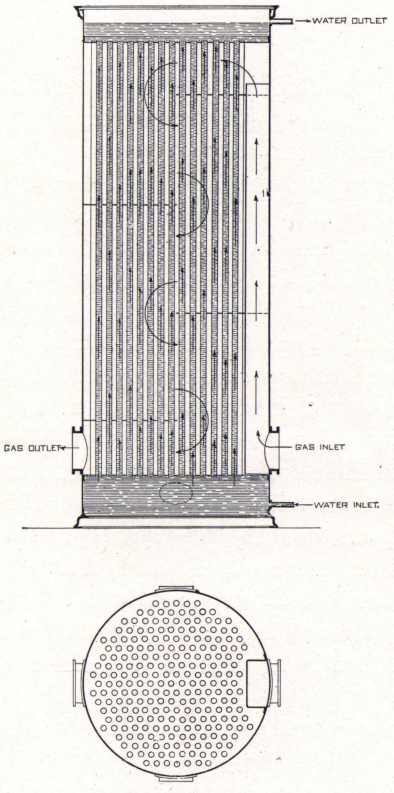


Fig. 11

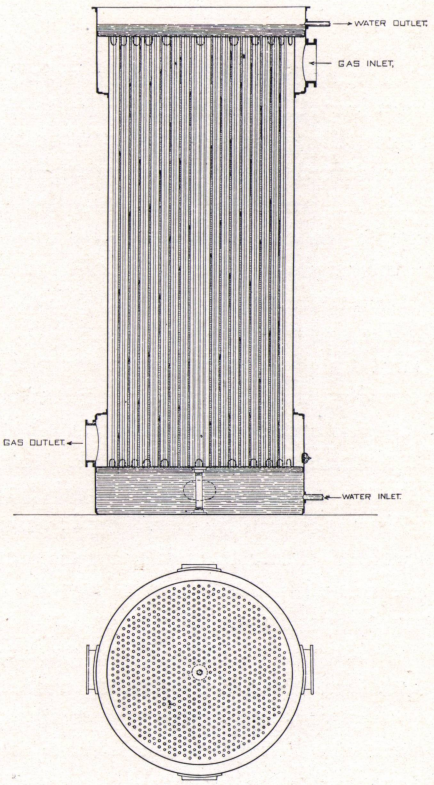


Fig. 12

of the amount for evaporating, such excess of water collecting in the bottom chamber of condenser, and passing thence to the waste pipe, or a small pump may be operated by the same power which actuates the blower and deliver the water to an overhead tank, from which it may feed by gravity back through the condenser. This water will, of course be warm, but as the conditions under which such a condenser is intended to operate will be at high temperature, there will be no particular objection to the water being warm, as it will then more readily evaporate and the heat will be taken up by the water far more rapidly when converted into *latent* heat of evaporation than when taken by the water as *specific* heat measured by temperature.

Latent Heat.

In this type of condenser, considerable increase of efficiency is obtained by suspending small baffles in the flues, causing repeated deflection of the ascending air against the wet surface of the flues. These baffles and the water jets are all made easily removable so that the condenser is quickly convertable into the ordinary type of air condenser. In a case of extremely wide ranges of temperature, this type of vaporizing condenser may be used in connection with and preceeding an ordinary air condenser, thus enabling the condensing plant to cope with extreme ranges of temperature without excessive cost or objectionable changes of construction in the units themselves.

Vaporizing Baffles.

Extreme Range of Capacity.

Secondary Condenser

The second unit in the cooling portion of the condensing system, namely, Secondary Condenser, will receive the gas at a temperature of about 90° to 100° F. according to the temperature at which it is found best to remove the tar from the particular gas under treatment, but never much below 90° F., because 90° is the practical limit of reduction in the primary condenser, and the gas may be below this only by as much as the temperature may be reduced in traversing the gas connections, from the P. & A. tar extractor to the secondary condenser. The gas at the outlet of the secondary should be within the range of 75° to 80° F., according to local conditions. The construction of the secondary condenser is very similiar to that of the primary, excepting that the range of temperature being much less and also because of the difference of temperature between the gas and cooling medium, called the *potential* of temperature, being much less than in case of the primary, it becomes necessary to take advantage of the greater frictional effect of the cooling medium by dividing it into smaller streams than in the primary, and therefore while the primary condensers may have tubes 4, 6, and often 8 inches in diameter, according to conditions, the secondary condenser will have tubes about 3 inches or sometimes 4 inches in diameter. The same conditions as to velocity of gas and frictional effect is to be observed in the secondary as in the primary condenser.

Conditions Different from Primary.

Size of Tubes.

Figure 9 illustrates the usual type of secondary condensers, and it will be noted that this condenser is also made with provision for using water instead of air as the cooling medium. In case of extreme increase of capacity being required, vaporizing condensers may be used as secondary, but are not recommended under ordinary conditions, as the effect would be the too rapid cooling of the gas.

Ordinary Style.

For the final cooling of the gas, water condensers are used usually with the gas circulating around the tubes as in the case of the primary and secondary, and sometimes with the water circulating through the tubes as does the air in the primary and secondary. All condensers are, of course, provided with suitable manholes and hand holes as required for access to the interior, and for any cleaning out necessary. This final or water condenser will reduce the temperature of the gas to be about 60° to 70° F., according to local conditions, after which the gas is ready for washing and scrubbing, which portion of the treatment is described in our bulletins Nos. 202 and 202—A.

Water Tubes and Gas Tubes.

Final Condensers.

Figure 10 illustrates the usual type of final condenser with the gas circulating around the tubes, and water through them. Figure 11 illustrates this same kind of condenser but with internal inlet flue by use of which the nozzles for connecting gas mains are brought to the same level.

Another type, which, however, is now being gradually displaced by the one shown in Figure 10, is that in which the gas passes through the tubes and the cooling medium circulates around the tubes but it is recommended for special conditions only.

Figure 12 illustrates still another form having annular inlet and out chambers provided with openings around the main shell for evenly distributing the entering gas and evenly collecting the outgoing gas.

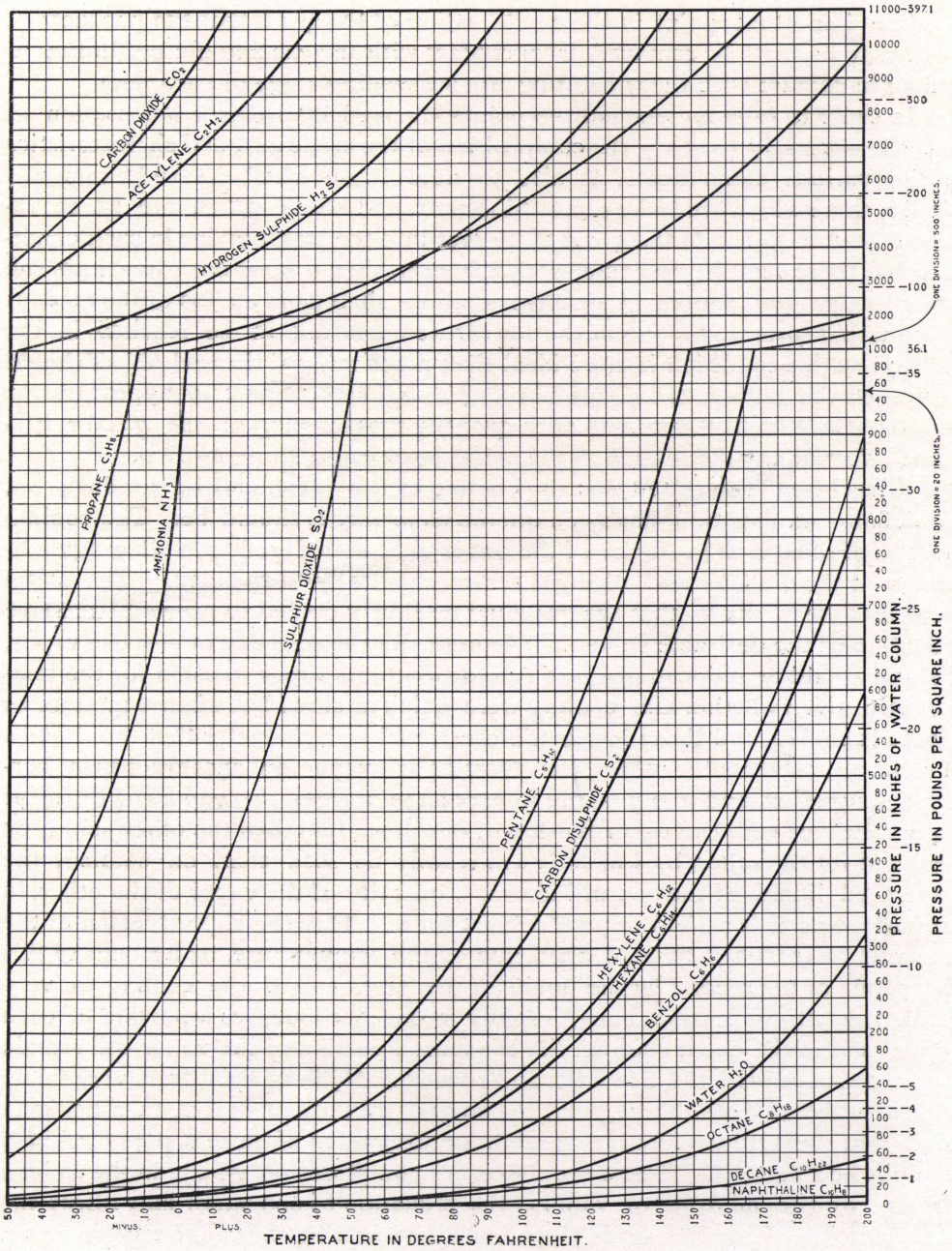


Fig. 13.

Vapor Tensions of Various Substances.

Remove Condensed Liquids.

One important point in the condensation of the gas is that the products of condensation shall be removed from contact with the gas and not be allowed to remain in contact with the gas during any succeeding stage of treatment.

Study Crude Gas.

In order to fully understand the points involved in proper condensation of gas, it is necessary to study the composition of the crude gas, and characteristics of the various components, as also to note those which are to be removed wholly, those which are to be removed in part, and those which are to be retained in the gas. If the gas is to be sent into the street mains in such condition that there shall be no condensation from it, then it must not carry into the street mains any vapors in quantities which shall be in excess of the amount which would saturate the gas at the lowest temperature to be reached in the mains; but this condition is more ideal than practical, and the real object should be to send the gas into the mains carrying its full complement of hydrocarbons, but Naphthalene must not be in such quantity that cooling of the gas or frictional effect of any circulation in the mains shall cause its deposition.

Gradual Cooling.

It has often been stated that the cooling of the gas should be gradual, but no definite explanation has been offered as to why it should be. The cooling must be gradual if the velocity of the gas is to be so reduced as to allow agglomeration of the globules and other matter mechanically suspended. The statement has been made that the gas must be slowly cooled to prevent excessive reduction of the desirable vapors. Theoretically the quantity of any one vapor, if alone, would be reduced in exact proportion to its vapor tension for the temperature given whether the cooling were quick or slow, but when a mixture of vapors is cooled, and those in the mixture are of such character that the liquids of some are solvents for others, the effect of one vapor on another has a corresponding effect, and it is possible to make a mixture of two vapors of different vapor tensions with the vapor tension of one much less than the other, and it be a solvent for the other, by which it will readily be seen that, on cooling, the condensed liquid of the one will absorb a quantity of the vapor of the other, in proportion as it is a good or poor solvent for it. Thus the vapor tension of the two will be reduced beyond that due to the temperature, on account of this absoprtion of the second by the liquid of the first, and if the cooling is very rapid, the vapor tension being rapidly reduced condenses a portion of each vapor, and in the quick cooling, the condensed portion of the vapor will remain for a time suspended as a fine mist, and consequently in a liquid form very finely divided and distributed throughout the body of mixture of vapors, thus being in condition, theoretically, most favorable for absorption of those vapors for which it might be a solvent. There are also other conditions on which, in the sudden cooling of the mixture of vapors, the reduction of one vapor may affect the vapor tension of another, usually spoken of as lowering the vapor tension curve. Hence it will be seen that the slower the condensation, the better will the condensed vapors agglomerate and deposit at the temperature at which they are condensed instead of remaining as a mist suspended in the mixture while the

Action of Vapors in a Mixture,

Relative Vapor Tensions.

Suspended Liquids.

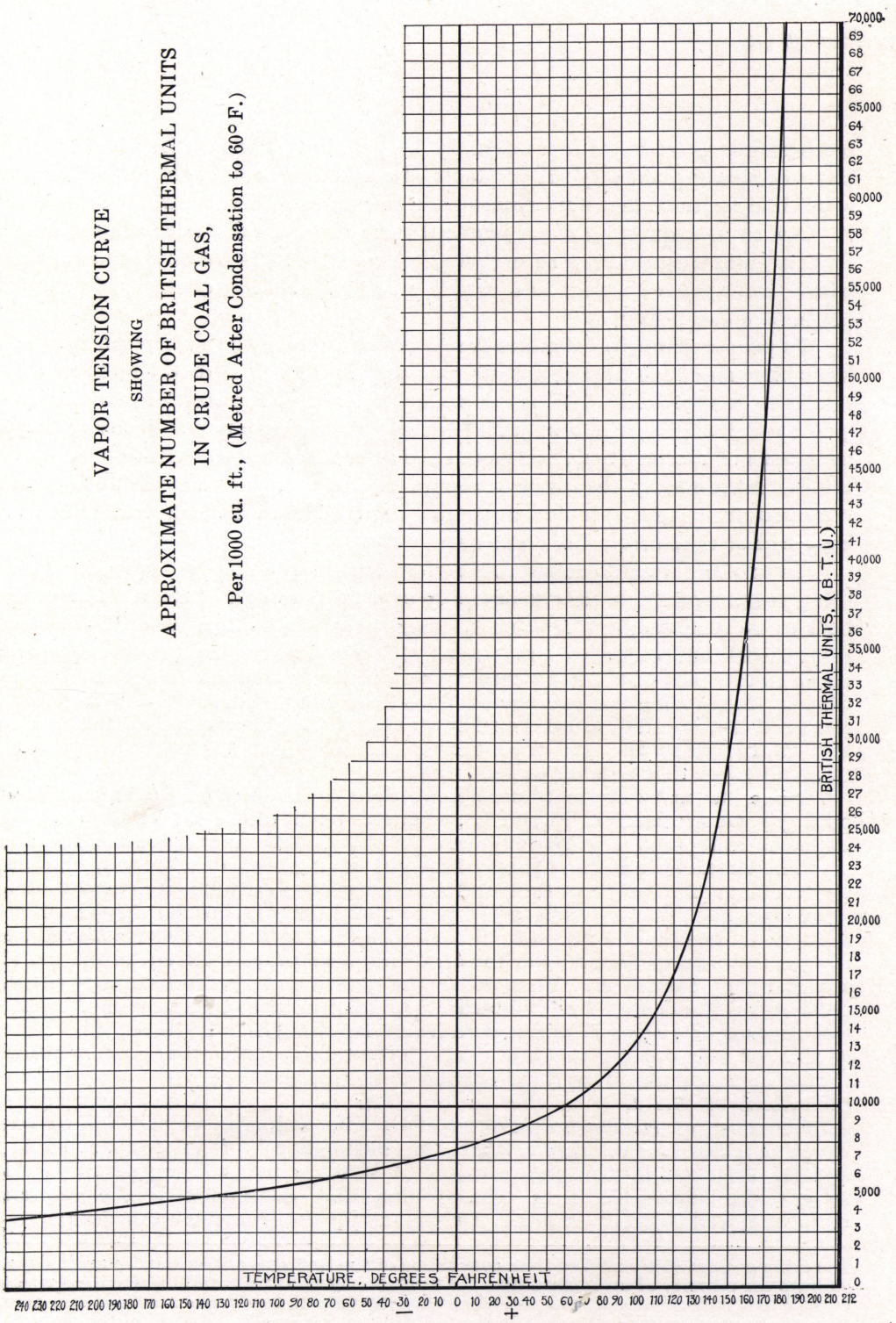


Fig. 14.
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Time for Agglomeration.

temperature is reduced considerably below that at which the mist is formed; this will also explain why the products of condensation at each stage of cooling should be removed and not be permitted to remain in contact with the gas.

Tar Removal.

As to the question of tar removal there is a wide diversity of opinion, and on this point we would refer the reader to bulletin 201—A supplement No. 2 which will appear shortly, and which will deal with the question of tar versus pitch, soot and heavy oil.

Proportioning Condensers.

In proportioning condensers for gas works, one of the first requisites is to know the amount of heat as usually measured in British Termal Units (B. T. U.) that is to be removed. This is determined from the composition of the crude gas by calculating the amount of specific heat to be removed from the vapors and gases in cooling them, the amount of latent heat of vaporization to be removed in reducing the excess vapors to liquids, and the specific heat to be removed from these liquids in cooling them down to the temperature at which they will be taken from the condenser.

Aqueous Vapors.

In making this calculation, it is very soon found that the aqueous vapor in the gas is accountable for considerably over 90 per cent. of the total amount of heat to be removed; in fact such a large percentage that in ordinary rough calculations the other vapors may be ignored. The importance of the aqueous vapor in this part of the gas treatment will be readily understood from the fact that in condensing an average coal gas from 140° F., to 60° F.. there must be removed considerably more thon 13000 B. T. U. per 1000 ft., of finished gas and to condense the gas from 165° F., to 60° F., necessitates the removal of of about twice that number of heat units.

Heat Units to be Removed.

As a summary of the thermal conditions to be taken care of in condensing coal gas, we illustrate in Figure 12, a curve from which an experienced gas engineer may read a great range and variety of data on coal gas condensation.

Graphic Summary.

The character and conditions of the gas having been determined, the cooling medium and range of temperature having been decided, it is easy to determine how much cooling surface will be required for any ordinary type of condenser. It is simply a question of converting the total heat to be removed from the gas into the specific heat in the air or water employed, except in the case of a vaporizing condenser. Then comes the question of heat transference through the metal of the condenser. There are two points first to be determined, namely the *amount of surface* required, and if tubular condenser be used, the *velocity of flow* of the cooling medium through the tubes or along the cooling surface. It is at once apparent that if the condenser be of usual type with upright tubes, the *velocity* of the flow of the air or water is of just as much consequence as the *area of cooling surface*, as it is the velocity of the air or water which enables us to insure that the entire area of each tube shall be equally effective in the transmission of heat, as by so doing we are enabled to get the maximum heat transmission and consequently the minimum metal required to do the work. In the majority of condensers designed by

Heat to be Disposed of.

Surface and Velocity.

The table on page 15 is compiled from over thirty of the best authorities, but the unfilled spaces indicate the scarcity of available data. As undoubtedly this bulletin will reach many who will be able to supply missing figures; we will be greatly pleased to receive additions and corrections for publication in supplement to this bulletin, giving credit always to the party from whom fresh data may be received. *Averages for quantities usually found.

The Western Gas Construction Co.

PRINCIPAL COMPONENTS OF CRUDE COAL GAS.

NAME	SYMBOL	NORMAL STATE	% BY VOLUME	% BY WEIGHT	SPECIFIC GRAVITY SOLID	SPECIFIC GRAVITY LIQUID	SPECIFIC GRAVITY GAS	LBS PER M COAL GAS	CU.FT. PER POUND	LBS. PER CU. FOOT	MELTING POINT	BOILING POINT	SPECIFIC HEAT LIQUID	SPECIFIC HEAT GAS	HEAT OF VAPORIZATION	IGNITION TEMP.	COMBUSTION B.T.U. PER LB.	FLAME TEMP.	SOLUBILITY IN WATER	ILLUMINATING PROPERTY
Hydrogen	H_2	GAS	44.983	5.775			.6967	2.4012	187.42	.005338		-418		3.409			62032		19.3	SLIGHT BLUE
Carbon (Soot)	C_2	SOLID	LAMP BLACK	.388	3.53		.8300	.1614	15.234	.063578		SUBLIMES					20388		INSOL.	?
Methane (Marsh Gas)	CH_4	GAS	32.223	32.895			.5544	13.6841	23.557	.042467		-263.2		.5929	1232		24071		41.1	5.2 PALE YELLOW
Ethane	C_2H_6	"	1.927	3.567		.394	1.0391	1.5338	12.563	.079595		- 89.5			1141		22388		94.5	35.7 BLUISH
Propane	C_3H_8	"	.882	2.459			1.5238	1.0229	8.566	.116723		-4.			1017		21664		ALMOST INSOL	56.7 LUM.
Butane	C_4H_{10}	"	.361	1.336		.600	2.0085	.5554	6.501	.153851		36.5					21374		" "	STRONG LUM.
Pentane	C_5H_{12}	LIQUID	.196	.900		.626	2.4932	.3742	5.248	.190979		97.34							" "	BRIL'NT FLAME
Hexane (Propyl)	C_6H_{14}	"	.087	.478		.664	2.977	.198	4.379	.228107		155.2	.5042		1476		20792		" "	BRIGHT LUM.
Other Paraffines	C_nH_{2n+2}	L'S & S'S	.051	.368		.700UP	.0695(7n+1)	.1530	*3.333	*.300	100UP	208UP	.487+	.712+					INSOL.	$\propto C/K-(CONST)$
Ethylene (Olefiant Gas)	C_2H_4	GAS	1.076	1.921			.9694	.7990	13.467	.074256		-152.5		.4040			21344		161.5	68.5
Propylene	C_3H_6	"	.574	1.537		1.036	1.4541	.6393	8.978	.111384		-77.8			939		21446		230	123 VERY GOOD
Butylene	C_4H_8	"	.272	.971			1.9388	.4039	6.732	.148512		23.0					21298			123.1 " "
Pentene (Amylene)	C_5H_{10}	LIQUID	.320	1.428		.655	2.4235	.5940	5.386	.185632		102.2	1.060	.773	135.7		20706		SLIGHTLY	VERY GOOD
Other Olefines	C_nH_{2n}	"	.095	.594		.699UP	.4847n	.2470	*3.846	*.260		155UP							MOSTLY INSOL	
Ethine (Acetylene)	C_2H_2	GAS	.326	.541		.451	.8997	.2247	14.511	.068917	-113.8	-121		.4040	1076	806	21778		1021	273 VERY FINE
Propine (Allylene)	C_3H_4	"	.096	.245			1.3844	.1018	9.434	.106045							21345			
Other Acetylenes	C_nH_{2n-2}	LIQUID	.042	.182			.0695(7n+1)	.0756	*5.555	*.180		98.6UP								
Benzene (Benzol)	C_6H_6	"	1.946	9.672		.885	2.6991	4.0234	4.838	.206751	40.1	176.74	.3952	.2990	183.6		18135		1.45	700 VERY FINE
Toluene (Toluol)	C_7H_8	"	.165	.968		.871	3.1838	.4024	4.101	.243879		231.26	.381		177.4		18311		.06	GOOD
Other Benzols	C_nH_{2n-6}	"	.132	.889		.862UP	.0695(7n-3)	.3696	*3.571	*.280		259UP							ALMOST INSOL	"
Naphthalene	$C_{10}H_8$	SOLID	.327	2.667	1.158		4.4288	1.1093	2.747	.339246	174.2	424.49	.396	.421			17502		INSOL.	900 SMOKY
Other Naphthalenes	C_nH_{2n-12}	"	.091	1.050				.4368											"	QUITE GOOD
Diphenyl	$C_{12}H_{10}$	"	.073	.717			5.3285	.2980	2.449	.408163	158.9	489.2					17690			" "
Anthracene	$C_{14}H_{10}$	"	.034	.388		1.147	6.1585	.1614	2.121	.471741	415.4	680					17171		VERY SLIGHT	" "
Pyrene	$C_{16}H_{10}$	"	.027	.348			6.9885	.1445	1.867	.535319	298.4	701.6							INSOL.	" "
Chrysene	$C_{18}H_{12}$	"	.019	.276			7.8882	.1148	1.654	.604236	480.2	816.8					16935		"	" "
Oxygen	O_2	GAS	.532	1.085		1.124	1.1068	.4510	11.797	.084781		-296.86	.347	.2175	108.1		NONE		29.89	NONE
Aqueous Vapor (Water)	H_2O	LIQUID	1.722	1.976	.9167	1.00	.6230	.8218	20.954	.047722	32	212	1.006	.4450	1054.8		NONE		∞	"
Carbon Monoxide	CO	GAS	5.464	9.743			.9683	4.0527	13.483	.074172	-350	315.4		.2425			4370		24.3	BRIGHT BLUE
Carbon Dioxide	CO_2	"	1.376	3.855		.947	1.5217	1.6033	8.581	.116562	-94	-108.4	1.00	.2025	79.2		NONE		1002	NONE
Hydrogen Sulphide	H_2S	"	1.426	3.096			1.1788	1.2876	11.077	.090296	-121	-79.24		.2432			4940		32326	SLIGHT BLUE
Carbon Disulphide	CS_2	LIQUID	.079	.383		1.272	2.6332	.1593	4.962	.201703	-176.8	116.6	.2379	.1569	154.8		6152		1.6	BLUE
Nitrogen	N_2	GAS	1.372	2.453		.885	.9708	1.0202	13.452	.074363	-353.2	-317.2	.430	.2438	71.7		NONE		14.78	NONE
Ammonia	NH_3	"	.933	1.014		.830	.5899	.4216	22.134	.045186	-103	-28.3	.234	.5084	535.5				727200	"
Amines (Mostly Methyl)	$(CH_2)_nNH_3$	GAS					.6(.8n+1)		*7.143	*.140		32 UP							104000	FAIRLY GOOD
Ammonium Sulphydrate	NH_4HS	SOLID					1.7687		7.382	.135482	14	SUBLIMES							SOLUBLE	NONE
" Sulphocyanide	NH_4CNS	"					2.6343	1.500	4.958	.201787	318.2								"	"
" Cyanide	NH_4CN	"	.750	3.709	1.573		1.5252		8.53	.116830		96.8							"	"
" Carbonate	NH_4HCO_3	"					2.7346		4.779	.209470	140DCOM								183	"
Phenol (Carbolic Acid)	C_6H_5OH	"	.021	.126	1.065		3.2524	.0523	4.003	.249134	107.6	359.6					14125		49.2	

Calculations are based on International Atomic Weights, British Thermal Units, Fahrenheit Thermometer and Pounds Weight. Specific Gravity of Solids and Liquids referred to Water, and Gases and Vapors to Air. Composition refers to Dry Gas at about 100° F. Pounds per M. and Cu. Ft. per lb. at about 60° F. SPECIFIC HEATS are *not constant* and figures given are fair averages for range from 100° F to 60° F. Solubility in water is per 1000 parts of water. Illuminating value figures are Candles per 5 cu. ft. gas per hour at 60° F.

the old "rules of thumb," it will be found that nearly all of the work done by the condenser is done in very much less than the full length of the tube, even when the condenser is working at its maximum practicable rate. It will therefore be seen, as has been frequently demonstrated in our practice, that the most common error in designing condensers is to put in an excessive number of tubes with the idea simply of getting a certain amount of cooling surface, and with one result, that the rate of flow of the air or water is so slow that the maximum temperature of the cooling medium will be attained before it has traveled the full length of the tube, and consequently the remaining length of the tube will be useless. Such designs result in too rapid action near gas inlet the condenser and no action near the outlet, showing that the amount of surface is *far greater than is required for the cooling medium* to uniformly absorb all the heat it can from the gas. The common remedy for such ill-designed condensers is to plug both ends of a number of tubes, thereby proportionately decreasing of the exposed cooling surface and to increase the velocity of the cooling medium until a proper balance is obtained. Careful tests have shown the absolute fallacy of attempting to design condensers on a basis of cooling surface *only*, as proper designing must necessarily be based on engineering principles involving several factors, all of which must receive proper consideration to produce the best result. This principle was fully demonstrated by this Company several years ago and information of it was noted and many tests were made by gas engineers as indicated by the discussion on condensers at the Chicago meeting of the Western Gas Association, May 16, 1900, noting particularly the experiment described by Messrs. B. E. Chollar and O. O. Thwing, which were carried out on suggestions made by this Company, that the metal of ordinary condenser construction was wrongly distributed and a remedy was suggested. To illustrate the various ideas of different people on the matter of condensing surface it is only necessary to quote a few statements as follows:

Distribution of Work.

Tests Made.

Butterfield referring to air condensers, says "from 150 to 200 sq. ft, of condensing surface should be allowed for each 1000 ft. of gas passing per hour."

Herring says; "It is somewhat difficult to fix any such area unless all the circumstances are known, but it may be taken as a general rule when wrought iron mains are employed, to allow five superficial feet of surface for each one thousand feet of gas production per 24 hours, the area being calculated from the outlet of the hydraulic main to the outlet of the condenser."

Old Rules.

Newbigging says, "It may be taken as a general rule that about ten superficial feet of atmospheric condensing surface for each one thousand cu. ft. maximum gas production per day of 24 hours should be provided. This is assumed to include the length of the foul main extending from the hydraulic main. Moreover, the condenser should be protected from the direct action of the sun's rays, or otherwise water should be made to trickle down the outer surface of the pipes during sunshine."

King's treatise says that when atmospheric condensers are employed they

"should have a superficial area of ten feet for every one thousand cu. ft. maximum production per diem, and all proper protection should be adopted to protect the apparatus," from great temperature changes, etc.

Vary Greatly.

Clegg gives one hundred and fifty superficial feet per one thousand feet per hour when the layer of gas is not over three inches thick.

Another authority says, a surface of 54 square feet is ample for cooling thirty-five thousand cu. ft. of gas in 24 hours, equal to one square foot per six hundred fifty cu. ft. in 24 hours.

O'Connor says "The pipes from the hydraulic main should have a superficial area of ten sq. ft. per thousand cu. ft. made per diem", also "Area required for condensation equals about four sq. ft. cooling surface (air) per gallon of water yielded per ton." Also "In water tube condensers about 2½ sq. ft. of cooling surface is allowed per 1000 cu. ft.." Other rules are given and the variation between authorities is oftentimes something wonderful. It is safe to say that most "rules of thumb" are merely an outcome of comparing condensers built by guess, gradually working down to limiting sizes by imitation of previous construction, at the same time economizing in first cost, not only as to details of design but with astonishing disregard of the proper determining factors. The character of the gas and the cooling medium being known, it becomes a question of heat transference through the metal, and on this point, although opinions differ widely experiment has proven that the co-efficient of heat transference varies with the character and thickness of the substances through which the heat is transmitted, and also varies with the temperatures at which the transference takes place. It must therefore be noted that with the same *potential* of temperature, (difference of temperature between the gas and water or air at any specific point)the heat transference will be less at a low temperature than at a high temperature, and it must also be noted that the specific heats of gases, vapors and water are by no means the same at all temperatures.

Co-efficient Varies with Temperature.

Heat Potential.

Having determined the range of temperature and the potential and the proper co-efficient for transference to be used, the proportion of condensers can then be definitely determined, but due attention must be paid to the frictional effect of baffling the gas in its progress through the condenser, as by proper attention to this point, the efficiency of an ordinary condenser may be increased from 40 per cent. to 60 per cent. in proportion to the manner in which the principle is applied. Special attention must also be given to the number and size of the tubes to insure a balance between the cooling area and the velocity of the absorbing medium, in order to maintain as nearly as possible a uniform potential of heat throughout the whole length of each tube.

Gas Baffles.

It is needless to say that our condensers are always proportioned for the work to be done in order to gain the maximum efficiency with the minimum of first cost consistent with the proper practical design that will give the greatest convenience and economy in commercial operation with elasticity of capacity.

In the operation of our system of condensers, reference being had to Fig. 16, the flexibility of the system will at once be apparent. In the case of new installations it is always wise to have a considerable reserve capacity to meet the natural growth of the business and consequently when a condensing plant is first put at work, its total capacity will probably be much in excess of first needs. In this case the work done by the final condenser is easily controlled by regulating the amount and speed of water circulating through it, and the secondary and primary condensers are likewise easily controlled by means of the dampers in the stacks restricting the air flow through the tubes. As the output increases and more work is required of the condensers, the water flowing into the final may be increased and the air flow into the secondary and primary may also be increased until the normal capacity of the apparatus is reached, when the dampers will be wide open. To meet further increase of output, the principal variation of load will call upon the primary and secondary condensers. Should more work be required of the secondary, the water overflowing from the top of final condensers may be turned across the top head of secondary by means of valve shown in the water connection, and if no increase is required in the primary, the water will then overflow to the sewer from top of secondary, but if small increase of work is also required of primary, the water overflowing from the secondary may be turned across the top head of the primary in the same manner, overflowing thence to the sewer. It will be noted that the tubes in the primary and secondary condensers extend above the top tube sheet about 6 inches so that the water flowing over the heads will not pass down the tubes, unless it should be desired that they be partially converted into vaporizing condensers.

Flexibility of System.

Capacity for Increased Work.

Should still further increase of capacity be required the course of the water from the top of the final condenser may be changed so that closing the air openings in the bottom of the secondary, the water may then enter the bottom chamber, passing up through the tubes from which it will overflow onto the top head and then flow to the primary. If no further increase is required of the primary the water may simply flow across the top tube sheets, but if it is desired also to materially increase the work done by the primary, the air openings in bottom chamber may be closed, and the water from the secondary caused to enter there and flow up through the tubes of the primary, overflowing thence to the top tube sheet and thence to the sewer, thus converting either the secondary or primary or both into water tube condensers, similiar to the final condenser, thus giving a range of capacity in the same apparatus unequaled by any other construction, and at the same time without deviating from the proper method and sequence of treating gas.

Water Flow.

Temperature.

In operating any condensers it is always necessary that thermometers be applied at the proper points in the inlet and outlet pipes but never in the shells, to determine the work done by the condensers and regulate them accordingly. We also apply automatic thermostat regulators by which the temperature of the gas itself controls the flow of the water and air, thus keeping this part of the treatment of the gas regulated to a nicety through wide variations of temperature and quantity of gas. The matter of thermometers will be treated in a special bulletin as will also the matter of arrangements for drip overflow.

CLAIMS ALLOWED IN U. S. PATENT No. 790,297.

Having described my invention, what I claim, and desire to secure by Letters Patent, is—

1. A tubular gas cooler and condenser having at the lower end an air inlet and chamber opening into the tubes, and at the top an air-outlet provided with a damper or valve for regulating and controlling the flow of air, and thus regulating the temperature of the gas, also having at the top a water-receptacle, upwardly-projecting tube ends therein, and means for controlling the supply to, and discharge of water from, said receptacle, and gas inlet and outlet pipes connecting with the shell inclosing the tubes, subtanstially as described.

2. The combination with an upright tubular condenser, having an air inlet and chamber opening into the tubes at the bottom and an outlet-chamber and tube sheet or head at the top, through which project the tube ends 7 , of a water-supply pipe having a valve opening above said head, whereby water may be caused to cool the head and to flow in films down the tubes while air is passed up through them, and gas inlet and outlet pipes connecting with the shell inclosing the tubes, substantially as described.

3. A tubular gas cooler and condenser, constructed with upper and lower tube sheets or heads, tubes extending throngh the same and having upwardly-projecting ends 7^a, in inlet and outlet chambers for the cooling fluid at top and bottom, water supply and overflow pipes connecting with the upper chamber above the tube-sheet, transverse baffle-plates extending from opposite sides of the shell for deflecting the gas back and forth around the tubes, gas inlet and outlet pipes connecting with the shell, substantially as described.

4. The combination with a gas cooler and condenser, constructed with upper and lower tube-sheets, connecting-tubes, and inlet-chamber at the bottom having an air-inlet, and an outlet-chamber at the top, of a water-supply pipe, having a valve, connecting with the bottom inlet-chamber, a water-outlet pipe connecting with the top outlet-chamber and means for closing said air-inlet, substantially as described.

5. The combination with a gas cooler and condenser, constructed with upper and lower tube-sheets, connecting-tubes, upper and lower inlet and outlet chambers for cooling fluid having air inlet and outlet openings, of a valved water-supply pipe connecting with the upper chamber, an outlet water-pipe connecting with the said chamber, a valued water-supply pipe connecting with lower chamber, and means for closing said air-inlet, substantially as described.

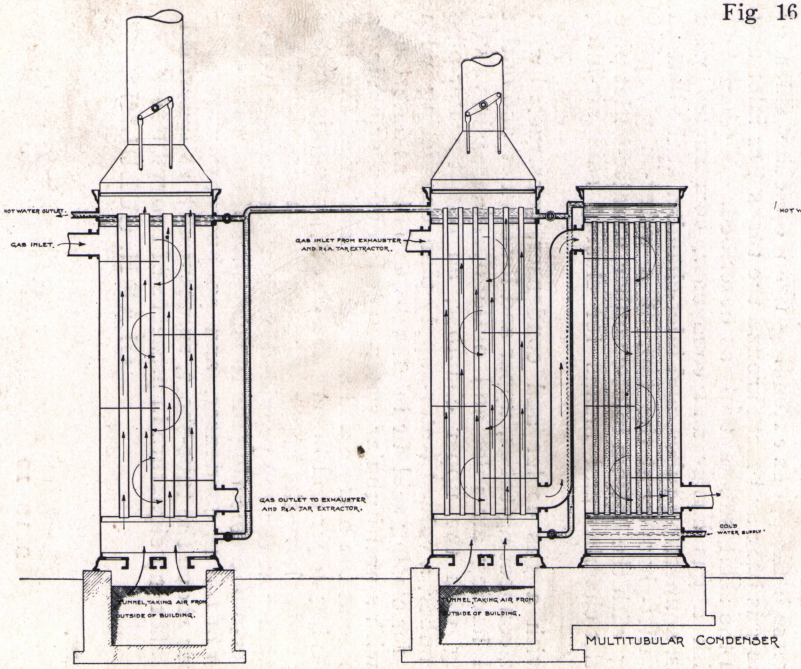
6. The combination with a multitubular water-cooled condenser having a water chamber and supply pipe at the bottom and an outlet-chamber at the top, of a tubular air-condenser having upper and lower tube-sheets, connecting-tubes having upwardly-projectlng ends above the upper tube-sheet, an air-inlet at the bottom and an air-outlet chamber at the top provided with a controlling valve or damper, and a valved water-pipe connecting the top chamber of the water-condenser, with the top chamcer of the air condenser, and an overflow water-pipe connecting with said chamber above the tube-sheet, substantially as described.

In testimony whereof I affix my signature in presence of two witnesses.

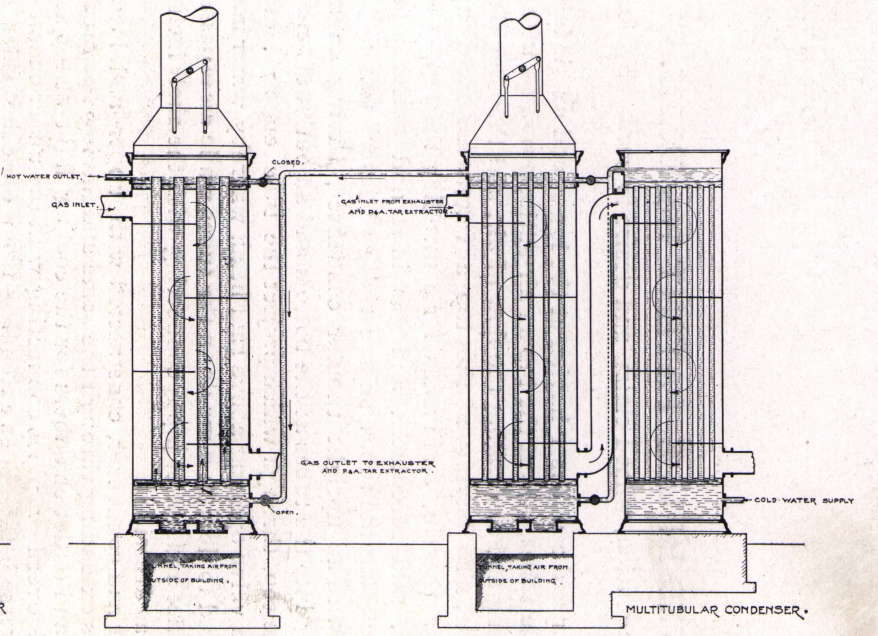
OLAF N. GULDLIN

Witnesses:
THEO. H. SCHEUMANN,
R. S. ROBERTSON.

Fig 16


HOT WATER OUTLET.
GAS INLET.
GAS INLET FROM EXHAUSTER AND P&A. TAR EXTRACTOR.
GAS OUTLET TO EXHAUSTER AND P&A. TAR EXTRACTOR.
COLD WATER SUPPLY.
TUNNEL TAKING AIR FROM OUTSIDE OF BUILDING.
MULTITUBULAR CONDENSER
PRIMARY COMBINATION AIR AND WATER CONDENSER.
SECONDARY COMBINATION AIR AND WATER CONDENSER.

VIEW SHOWING PRIMARY AND SECONDARY CONDENSERS WHEN COOLED WITH AIR, AND WATER OVERFLOW FROM MULTITUBULAR CONDENSER PASSING OVER TOP HEADS.


HOT WATER OUTLET.
CLOSED.
GAS INLET.
GAS INLET FROM EXHAUSTER AND P&A. TAR EXTRACTOR.
GAS OUTLET TO EXHAUSTER AND P&A. TAR EXTRACTOR.
OPEN.
COLD WATER SUPPLY
TUNNEL TAKING AIR FROM OUTSIDE OF BUILDING.
MULTITUBULAR CONDENSER.
PRIMARY COMBINATION AIR AND WATER CONDENSER.
SECONDARY COMBINATION AIR AND WATER CONDENSER.

VIEW SHOWING CONDENSERS WHEN COOLED ONLY WITH WATER.

BULLETIN No. 201. ERRATA.

On page 4, under Fig. 3, please change date to December 11th, 1901. On page 6, Figs. 4 and 5, are reduced from our drawing made February 22nd, 1901. On page 16, Fig. 12 is looking *from* exhauster room, on page 17, Fig. 13, is looking *towards* exhauster room.

NOTICE.

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